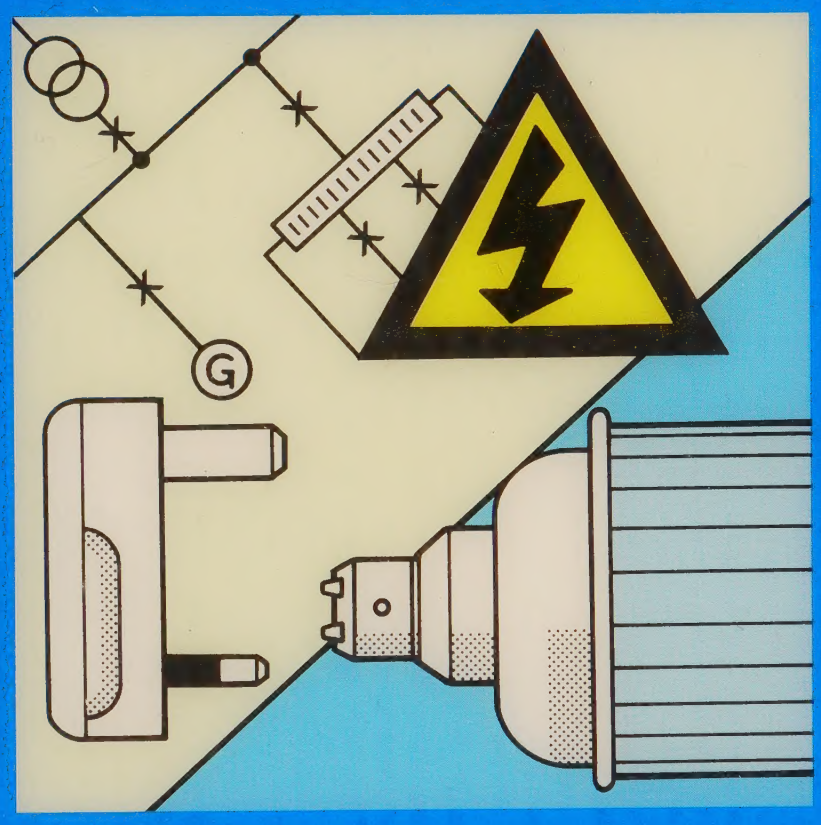
MC0173

Health Technical Memorandum 2007

Validation and verification

Electrical services: supply and distribution



725.
51
GRE

Health Departments

NHS Estates
An Executive Agency of the Department of Health

Digitized by the Internet Archive
in 2025 with funding from
UCL Library Special Collections

https://archive.org/details/ucl_mc0173

Health Technical Memorandum 2007

Validation and verification

UNIVERSITY LIBRARY

Electrical services: supply and distribution

LONDON SOUTH BANK
UNIVERSITY LIBRARY
WITHDRAWN FROM STOCK

London : HMSO

30102 00492580 4

NHS Estates
An Executive Agency of the Department of Health

© Crown copyright 1993
Applications for reproduction should be made to HMSO
First published 1993

ISBN 0 11 321686 6

HMSO
Standing order service

Placing a standing order with HMSO BOOKS enables a customer to receive future titles in this series automatically as published. This saves the time, trouble and expense of placing individual orders and avoids the problem of knowing when to do so. For details please write to HMSO BOOKS (PC 13A/1), Publications Centre, PO Box 276, London SW8 5DT quoting reference 14 02 017. The standing order service also enables customers to receive automatically as published all material of their choice which additionally saves extensive catalogue research. The scope and selectivity of the service has been extended by new techniques, and there are more than 3,500 classifications to choose from. A special leaflet describing the service in detail may be obtained on request.

About this publication

Health Technical Memoranda (HTMs) give comprehensive advice and guidance on the design, installation and operation of specialised building and engineering technology used in the delivery of healthcare.

They are applicable to new and existing sites, and are of use at various stages during the inception, design, construction, refurbishment and maintenance of a building.

Health Technical Memorandum 2007

HTM 2007 focuses on the

a. legal and mandatory requirements;

b. design applications;

c. maintenance;

d. operation

of electrical services supply and distribution in all types of healthcare and personal social services premises.

It is published as four separate volumes, each addressing a specialist discipline:

- **Management policy** – outlines the overall responsibility of managers of healthcare and personal social services premises, and details their legal and mandatory obligations in setting up and operating reliable, efficient and economic electrical services. It summarises the technical aspects involved and concludes with a list of definitions;

- **Design considerations** – details the requirements and considerations that should be applied to the design of electrical services up to the contract document. Guidance is given on the choice of supply, distribution voltages, equipment, cabling and utilisation circuits. Typical system layout and sub-station/ switchroom configurations are also shown;

- this volume – **Validation and verification** – details the requirements for ensuring that

manufactured equipment is formally tested and certified as to contract, and manufactured to the highest level of quality assurance. The importance of commissioning is emphasised and the order of tests on site is listed. Routine testing, which is a subset of these commissioning tests, is also reviewed;

- **Operational management** – provides information for those responsible for overseeing and operating day-to-day running and maintenance. Coverage includes routine tests, planned preventive maintenance and troubleshooting.

Guidance in this Health Technical Memorandum is complemented by the library of National Health Service Model Engineering Specifications. Users of the guidance are advised to refer to the relevant specifications for "Electrical services".

The contents of this Health Technical Memorandum in terms of management policy, operational policy and technical guidance are endorsed by:

a. the Welsh Office for the NHS in Wales;

b. the Health and Personal Social Services Management Executive in Northern Ireland;

c. the National Health Service in Scotland Management Executive,

and they set standards consistent with Departmental Cost Allowances.

Statutory guidance on electrical safety to meet the Electricity at Work Regulations 1989 is published in HTM 2020 – 'Electrical safety code for low voltage systems' and HTM 2021 – 'Electrical safety code for high voltage systems'.

Guidance on emergency electrical requirements is published in HTM 2011 – 'Emergency electrical services'. Guidance on reduction of electrical interference is given in HTM 2014 – 'Abatement of electrical interference'.

References to legislation appearing in the main text of this guidance apply in England and Wales. Where references differ for Scotland and/or Northern Ireland, these are given as marginal notes.

Where appropriate, marginal notes are also used to amplify the text.

SOUTH BANK UNIVERSITY
CLASS NO. REPORTS/SERIES
DATE 1/94.
ACC. NO.

Contents

About this publication

1 Scope *page 3*

2 Works tests *page 4*
2.1 General
2.2 Type test certificates
2.3 Routine works test certificates

3 Site testing and commissioning *page 5*
3.1 Inspection of certificates
3.2 Witness of tests
3.4 Retention
3.6 Wiring diagrams
3.7 Commissioning

4 Pre-commissioning procedures *page 6*
4.1 Test administration
- 4.1 General
- 4.2 Test records of plant items
- 4.3 Contract requirements
- 4.8 Personnel
- 4.9 Witness of test documents
- 4.12 Electrical equipment for test
- 4.13 General inspection of equipment
- 4.14 Agreement to test

4.16 Site test procedures: switchboards and motor control centres
- 4.16 Sequence of tests
- 4.17 Initial inspection
- 4.23 Switching devices – mechanical functions
- 4.34 Switching devices – electrical functions
- 4.46 LV contactor equipment
- 4.58 Control equipment and secondary wiring inspection
- 4.61 Transformers – mechanical function tests
- 4.71 Transformers – electrical function test

4.83 Voltage transformers
- 4.83 Polarity
- 4.84 Ratio
- 4.85 Vectors

4.86 Cables
- 4.86 Cables and terminations
- 4.96 HV cable test
- 4.103 Site HV tests on new buried cables
- 4.105 Integrity of cable outer sheath test

5 Electrical protection *page 15*
5.1 Test details
- 5.1 General test procedures
- 5.5 Test instruments

5.6 Relay tests
- 5.6 LV motor thermal overload device
- 5.9 Current transformers
- 5.15 CT balance test
- 5.16 Sensitivity of relays
- 5.17 Stability of relays

5.24 Secondary injection test equipment
- 5.24 Test plugs
- 5.26 Test variac transformer

5.27 Protection relay test criteria
- 5.27 Test arrangements
- 5.30 Primary injection test
- 5.34 Secondary injection test
- 5.35 Scope of relay testing
- 5.36 Tripping and alarm tests

6 Earthing *page 21*
6.1 Power systems
- 6.1 General earthing considerations
- 6.3 Fault current paths
- 6.7 Requirements for an earthed system
- 6.12 Recommendations
- 6.14 Electronic equipment
- 6.15 High frequency heating equipment (industrial and medical diathermy)

6.16 Earth electrodes
- 6.16 Location of main earth
- 6.18 Earth resistance measurement
- 6.21 Types of electrode
- 6.24 Protective conductors
- 6.27 Screened rooms
- 6.31 Battery earthing systems

7 Power and lighting circuits *page 25*
7.1 Inspection and testing
- 7.1 General
- 7.3 Identification of circuits and notices
- 7.5 Inspection of distribution boards
- 7.10 Sequence of tests
- 7.11 Ring main continuity and measurement test
- 7.13 Circuit protective conductor continuity test
- 7.14 High current test of a circuit protective conductor
- 7.16 Polarity

7.17 Insulation tests
- 7.17 Circuit tests

7.19 Earth circuit tests
- 7.19 General
- 7.20 Electrode resistance
- 7.21 Earth loop impedance

8 Sample test sheets *page 29*
8.1 Fixed panels and switchboard inspection
8.2 HV pressure test – switchboards
8.3 Switching devices – mechanical test

8.4 Switching devices – electrical test
8.5 Transformer – mechanical test
8.6 Transformer – electrical test
8.7 LV contactor gear
8.8 Motor thermal overload device: overload injection
8.9 Functional and IR test – secondary wiring
8.10 Secondary wiring injection test (tripping and auxiliary tripping relays)
8.11 Batteries
8.12 Battery charger – charge test
8.13 Battery discharge test
8.14 Cables and terminations
8.15 CT polarity test (flick test)
8.16 CT magnetisation characteristics
8.17 Secondary injection test (IDMT relay)
8.18 Secondary injection test (instantaneous relay)
8.19 Secondary injection test – instantaneous relay (voltage operated)
8.20 Restricted and standby earth fault relays (ref & sef) wiring and circuit resistance diagrams
8.21 Current transformer – primary injection test
8.22 Electrode – soil resistivity
8.23 Main/lightning earth electrode resistance

Other publications in this series *page 56*

About NHS Estates *page 57*

1.0 Scope

1.1 Electrical services form an integral part of the healthcare and personal social services premises (HCP) supply and distribution network in meeting both safety and functional requirements.

1.2 The provision of electrical services in HCP is a management responsibility at both new and existing sites. This guidance is equally applicable to premises which offer acute healthcare services under the Registered Homes Act 1984.

Nursing Homes and Agencies Act (Northern Ireland) 1971
Nursing Homes Regulations (Northern Ireland) 1974
Registered Establishments (Scotland) Act 1987

1.3 This guidance also provides an insight into the requirements of the Electricity at Work Regulations 1989.

Electricity at Work Regulations (Northern Ireland), SI 191/13

1.4 Healthcare and personal social services premises are totally dependent upon electrical power supplies, not only to maintain a safer and more comfortable environment for patients and staff, but also to give greater scope for treatment using sophisticated medical equipment at all levels of clinical and surgical care. Changes in application, design and statutory requirements have led to the introduction of a new generation of equipment and new standards of reliability; hence, a large expansion of material is included in the current HTM.

1.5 Interruptions in electrical power supplies to equipment can seriously disrupt the delivery of healthcare, with serious consequences for patient well-being. Healthcare and personal social services premises must therefore ensure that their electrical installation provides maximum reliability and integrity of supplies. Every effort must be made to reduce the probability of equipment failure due to loss of power from the regional electricity company and from internal emergency power sources.

2.0 Works tests

General

2.1 Each major item of electrical equipment should be type tested. This includes any equipment manufactured to the BS or IEC Standard. The need for type test certificates shall be as stated in the specification document.

Type test certificates

2.2 These certificates should be submitted with contractor's tender documentation and shall be issued by an approved test house. The test house must be registered by NAMAS or equivalent authority within the EC.

Routine works test certificates

2.3 These certificates shall be provided with each major item of electrical equipment, as tested, and must be approved by the HCP project manager (*the engineer*) before despatch from the works to site.

The term "engineer" refers to the management representative in charge of the works or any person nominated to represent the management

2.4 The routine works test certificate should be available to commissioning staff before "on-site" commissioning commences.

2.5 All equipment delivered to site should be stored in a warm and dry environment.

3.0 Site testing and commissioning

Inspection of certificates

3.1 When the installation has reached practical completion in accordance with the contract, a take-over certificate will be issued. This will certify the date on which the installation was taken over and the commencement of the maintenance/defects liability period.

Witness of tests

The term "contractor" also implies any person representing the contractor and acting on his behalf

3.2 There must be a formal and contractual procedure arranged between the *engineer* and the contractor for all plant verification before acceptance can be agreed.

3.3 The verification should include a thorough inspection of the installation to assess the quality and accuracy of the work and to witness any tests specified in the contract. The *engineer* shall witness all tests and inspections.

Retention

3.4 Minor defects or deficiencies relating to the work carried out by the contractor should be listed in the take-over certificate and corrected as early as possible during the maintenance/liability period.

3.5 Retention monies, as indicated in the contract document, should be paid on at the end of the maintenance/liability period when all rectification of defects or deficiencies has been completed. This should also include items provided by nominated suppliers.

Wiring diagrams

3.6 Wiring diagrams, instruction manuals, etc should be given to the engineer supervising the work, preferably at the time of commissioning, but no later than at hand-over.

Commissioning

3.7 Commissioning of equipment, as listed in the schedule of the contract document, must be accompanied by all the associated pre-commissioning data sheets. This should indicate full acceptance, or reservations in performance, by the *engineer*.

4.0 Pre-commissioning procedures

Test administration

General

4.1 The basis of pre-commissioning tests is to ensure that all tests are carried out by the contractor before any system or equipment is handed over to the *engineer*.

Test records of plant items

4.2 The original test records of all electrical equipment should be kept for future reference, whether as a reference to "as-fitted" levels of performance, or as the basis for future comparative designs and costs.

Contract requirements

4.3 All original forms of test records relate to the legal assurances as detailed in the contract document. Where a single level of performance is required, or interrelates to the overall reliability of the whole plant operation, the details of records required to ensure compliance must be negotiated with the contractor at the tender assessment stage.

4.4 The "specification document" must give guidance and contain direct indicators for all final tests required. This should indicate time requirement to validate the overall performances.

4.5 The cost of a rigorous verification programme is not low. Sufficient time must be identified within the project plan to allow for its execution.

4.6 Delays which can arise during the earlier phases of the construction programme must not be allowed to override this aspect of the contract.

4.7 Executive control and responsibility for achieving this should be effective.

Personnel

4.8 Good technical ability and integrity is required of staff carrying out the various test requirements. This would ensure that the results obtained are representative in establishing the effectiveness of the design and its operating provisions as stated or implied within the contract document.

Witness of test documents

4.9 It is essential that the procedures for all tests have been agreed in advance between the *engineer* and the contractor. Any deviations must be fully recorded.

4.10 The document must be witnessed by both the *engineer* and the contractor. The time and date shall be recorded and all observations noted.

4.11 If the results of a test do not conform to contract, they should be rejected, and a repeat or revised test demonstration negotiated.

Electrical equipment for test

4.12 Electrical supply and distribution equipment demand a high capital investment in any building project. The electrical equipment for test and documentation will comprise:

a. HV switchgear and associated controlgear;

b. LV switchgear and associated controlgear;

c. power transformers and associated controlgear;

d. HV cables and associated cable works;

e. LV cables and associated cable works;

f. control wire cables, associated cable works and marshalling cubicles;

g. earthing systems;

h. emergency generators and controlgear;

j. battery systems.

Emergency generators and battery systems are discussed in Health Technical Memorandum 2011 – 'Emergency electrical services'

General inspection of equipment

4.13 Before the start of any pre-commissioning test, the equipment and its associated installation should be carefully inspected and checks made to ensure:

a. cleanliness and suitability of enclosure;

b. location, positioning, level and structural rigidity, and freedom from vibration;

c. that labels/numbers are correct to the approved contract drawing;

d. that there is adequate heating, ventilation and isolation from any adjacent heat source;

e. that provision is made for the cable entries and terminations;

f. that holding-down bolts, clamps and cleats are connected;

g. that power and control cables are secured correctly;

h. that neatness of control wire looming is evident;

j. that all fuse links are of correct rating;

k. that all terminations are correctly numbered, permanently identified and correctly crimped;

m. that cable entries are secured against insect and vermin infestation;

n. that the electrical equipment is securely locked and materially secure from site theft or operational damage;

p. that an effective earth protective conductor is provided.

Agreement to test

4.14 All the required commissioning tests should be conducted at the permanent installation. No equipment may be formally tested without the agreement and knowledge of the *engineer*.

4.15 Adequate safety precautions must be applied, as required by HTM 2021 – 'Electrical safety code for high voltage systems' and HTM 2020 – 'Electrical safety code for low voltage systems' and Health and Safety at Work Regulations. The following should be observed:

a. the tests shall be carried out in accordance with normal good practice exercised in the electrical contracting industry;

b. all test equipment should be provided by the contractor, approved by the *engineer*, and be available on site for any planned test;

c. all instrumentation and metering should be accompanied by a recent test certificate of guaranteed accuracy;

d. all test results should be recorded on a mutually agreed test data sheet, and be dated and signed by the engineer and the contractor;

e. a register should be kept of names and signatures of all the engineer's and contractor's nominated representatives.

Site test procedures: switchboards and motor control centres

An approved test data sheet must be used to record each set of test results

Sequence of tests

4.16 The tests should be in five separately approved parts:

a. inspection and test of switchboards;

b. mechanical functional test of equipment;

c. electrical functional test of equipment;

d. electrical protection test;

e. trip and alarm annunciator test.

Initial inspection

4.17 Carry out a general inspection for damage and deterioration during storage.

4.18 Ensure labelling and warning signs on switchboards are correct.

4.19 Check the switchboard is fixed/mounted correctly to the base and structure.

4.20 Check the switchboard earth connection is connected to the main earth system.

4.21 For the following checks, the switchboard bus-bars must be either not connected or, if previously energised, isolated (earthed for HV) and an appropriate safety document for the work issued:

a. check manual freedom of operation of any circuit or bus-bar shutter door mechanisms;

b. check manual operation of shutter mechanical linkage, device racking mechanism and associated interlocks and keys;

c. check voltage transformer (VT) and current transformer (CT) compartments. Ensure the integrity of the assembly and the identification on the cover plates;

d. test, with a torque wrench, all phase bus-bars, neutral, and frame connected earth circuit-bar bolts to the torque values set by the manufacturer;

e. carry out resistance tests across all bus-bar bolted joints, using a low resistance ohmmeter (ductor). Also measure the resistance between cubicle bus-bar spouts and, for outgoing circuits, between the cable box phase terminations and the cubicle circuit spouts;

f. the resistance across closed circuit breaker contacts should be taken between each pair of phase isolating contacts. The readings should be uniform and approximately 40 micro-ohms per section of bus-bar, and 500 micro-ohms with the circuit breaker contacts closed.

4.22 With VTs isolated and CTs connected to earth, carry out the following measurements:

a. insulation resistance (IR) of VTs;

b. IR of bus-bars before and after HV pressure test;

c. HV pressure test of bus-bar, between phases and phase to earth, for one minute. Record any leakage current; BS5227 refers.

Switching devices – mechanical functions

4.23 Check all components are fitted correctly to approved drawings.

4.24 Check tightness of all secured/bolted fittings.

4.25 Check carriage switch alignments to cubicle sliding contacts.

4.26 Check alignment of switching device in cubicle.

4.27 Check manually the operation of bus-bars and circuit shutters.

4.28 Check manually the operation of isolating, service and earth mechanical semaphore indications.

4.29 Check manually the operation of all device-actuated auxiliary switches.

Trolley positions and indications are correct on the panel

4.30 Rack switching device into isolated, then service positions. Listen carefully to ensure that bus-bar and circuit shutters have opened before the switching device isolating contacts are fully entered into the bus-bar and circuit chambers.

4.31 Carry out mechanical close/open of switching device in service position. Observe open/close mechanical indications.

Trolley position and indications are correct on the panel

4.32 Where applicable, set up the earthing equipment, rack into the earth position and observe that only the circuit shutters open. The bus-bar shutters must remain closed and be locked.

4.33 Reinstate switching device.

Switching devices – electrical functions

4.34 Check the resistance of the long and short sliding contacts and auxiliary switch circuits on the switching device and in the cubicle for the protection, alarms and indication terminals.

4.35 With all fuse links and earth links removed, check IR of switching device of main circuits, CTs and control circuits.

4.36 Carry out HV pressure test of the switching device with closed main contacts between phases and phase to earth for one minute duration; BS5227 refers.

4.37 Repeat IR test.

4.38 Rack switching device into the service position.

4.39 Establish closing and trip supplies and observe switching device indications.

4.40 Open/close switching device, first manually for smooth operation, then electrically.

4.41 Check "close" coil operation at 80% rated voltage (applicable also to spring motor closing). Use power pack or variac transformer.

4.42. For spring "close" mechanisms, measure and record the time to fully charge the spring, at rated and 80% voltages.

4.43 Check "open" coil operation at 50% rated voltage.

4.44 Set up earthing equipment and operate.

4.45 Test maintenance jumper plug, socket and leads where provided.

LV contactor equipment

4.46 Check all components to general assembly drawing.

4.47 Check tightness of all fittings.

4.48 Check labelling and warning signs to relevant design requirement.

4.49 Check that frame earth connections are connected to the main earth.

4.50 Check all contactor flash guards and shrouds are effective and present, and that the main and auxiliary contacts are aligned.

4.51 Check mechanical interlocks and operation of door keys to cubicle.

4.52 Measure IR between phases and phases to earth. Ensure that all electronic equipment circuits are disconnected.

Use 500 V d.c. (IR) test instrument on circuits up to 500 volts

4.53 Check that all power and control fuse links are of correct type and rating.

4.54 Check operation of all d.c. contactor and relay coils at:

a. 80% rated voltage to "close";

b. 50% rated voltage to "drop off".

4.55 Check operation of all a.c. contactor and relay coils at:

a. 85% rated voltage to "close";

b. 75% rated voltage to "drop off".

4.56 Operate all contactors and relays five times at the rated voltage.

4.57 Check indications on panel are correct.

Control equipment and secondary wiring inspection

4.58 All circuits must be systematically checked and operated as per the relevant schematic diagram to ensure the electrical functional response of all components listed in the equipment schedule. All results should be recorded.

4.59 To conclude the test, check connections to earth, terminal tightness, secure end crimping, dust covers and safety shrouds. Ensure all test leads and shorting links are removed from the panel or cubicle.

4.60 Terminal lug crimping tools should be randomly and continuously checked by the *engineer* to ensure the approved lug crimp pressure is achieved. This is just as important for small wire terminations in control panels as in power cable terminations.

Transformers – mechanical function tests

4.61 Carry out a general inspection for damage and completeness of the assembly.

4.62 Ensure all components are fitted as shown in the general arrangement (GA) drawing.

4.63 Check all fastenings are tightly fitted.

4.64 Check labelling of transformer is correct.

4.65 Ensure transformer is positioned correctly and cable boxes and bushings suitably placed and aligned to receive cables.

4.66 If transformer is of breathing design, check if it is filled with oil or fluid. Take oil/fluid sample at drain valve.

4.67 Check breather is correctly fitted and desiccator crystals, if provided, are blue.

4.68 Check cable box details agree with LV and HV cable sizes and gland requirements. Also check that correct gland plates are provided and threaded ready for glands and HV bushings are sound and unmarked.

4.69 Check inside cable box for oil or fluid leaks and at joints surrounding all necessary entries.

4.70 Check operation of off-load tap changer over the operating range.

Transformers – electrical function test

Use a 1000 V d.c. (IR) test instrument for circuits above 500 V supply and a 500 V d.c. below 500 V

4.71 Carry out initial IR tests to HV and LV windings.

4.72 Check IR of all control, trip and alarm wiring with fuse links removed.

Use a 500 V d.c. (IR) test instrument

4.73 Set oil and winding hot spot temperature indicators to trip and alarm levels. Tank pressure trip and alarm should have been tested at the works.

Use a 1000 V d.c. (IR) test instrument for circuits above 500 V supply and a 500 V d.c. below 500 V

4.74 Check IR of iron core to earth, if core link is accessible for disconnection (in large transformers).

Glass bottles with ground glass stoppers should be used, particularly where analysis is delayed. The bottles should be initially oven dried and the stoppers finally sealed by wax

4.75 If transformer is to be filled with oil or fluid on site, test each drum sample **before** filling commences to BS148. For transformers of the conservator design, already filled, take a sample at the Buchholz relay and one at the tank drain valve.

4.76 Ensure oil/fluid is at the correct indicated tank level for the ambient temperature.

Use a 1000 V d.c. (IR) test instrument for circuits above 500 V supply and a 500 V d.c. below 500 V

4.77 Check IR of transformer windings.

4.78 To determine the transformer voltage ratio and vector configuration:

a. interconnect, by a single test wire, the HV and LV (A2 and a2) terminals;

b. apply: three phase 415 V a.c. supply to the transformer **high voltage** terminals. Measure and calculate the ratios of HV and LV, three-phase voltages, as indicated, at all off-load tap changer positions;

c. at the nominal ratio, take all available voltage levels between the HV and LV terminals. If an open tertiary winding is provided, check first with the manufacturer for this voltage;

d. confirm nominal voltage ratio is correct. Draw a vector configuration to confirm the transformer phase connections are correct (see HTM 2007 – 'Electrical services: supply and distribution' ("Design considerations", paragraphs 15.11 – 15.16).

4.79 Check the following alarms, trip relays or sensors as applicable:

Use current or gas injection

a. Buchholz alarm - by N_2 injection;

b. winding temperature;

c. tank pressure.

4.80 Check IR of cooling fan motor,if provided, followed by thermal overload current checks and the auto/manual functional cooling temperature control.

Use a 500 V d.c. (IR) test instrument

4.81 Before the initial energisation, carry out IR checks to HV and LV windings from the circuit breakers.

Use a 1000 V d.c. (IR) test instrument for circuits above 500 V supply and a 500 V d.c. below 500 V

4.82 If any delay occurs before continuous energisation, check before energisation that all protection trips, alarms and indications are operational. Ensure cable boxes are secure. A further oil sample may be required from tank drain valve.

Voltage transformers

Polarity

4.83 The polarity of VTs can be checked using the same test procedure as for CTs (see paragraph 5.14a). For the "flick test", care must be taken to connect the battery +/– leads, in turn, across only the phase end terminals, of the **high voltage primary winding** with the ammeter connected to the same phase of the **low voltage secondary winding** end terminals.

Ratio

4.84 The ratio check is made when the HV main circuit bus-bar is energised at rated voltage. The secondary winding line and phase voltages must then be at the expected operating voltages, normally 110 V.

Vectors

4.85 The phase sequence of rotation should be checked at the secondary winding terminals by a suitably rated voltage phase rotation meter. Special additional checks are required where there is a broken tertiary winding provided.

*The vector relationship may be obtained by connecting a three-phase 415 V a.c. supply to the **primary winding**. The primary winding input and secondary winding output phase and line voltages are measured. Finally, a vector diagram is drawn to check the polarity/connection between each phase winding (see paragraph 4.78)*

Cables

Cables and terminations

4.86 Carry out general inspection of cable route.

4.87 If cables are not terminated, check ends for correct identification and sealing.

The trench should ideally not be back-filled with soil until the HV d.c. tests have been satisfactorily completed on the cable outer sheath and core insulation

4.88 Check cable trench is of correct depth and bedded with sand and the cables spaced correctly with covering tiles and marker tape in situ.

4.89 Check tray work for completeness, and that the cables are placed at correct levels and spacing and are tidily arranged.

4.90 Check cables, in trefoil or flat pattern, are correctly secured to the tray with strap/cleat binders of correct non-magnetic material and are properly spaced.

4.91 Ensure cable entries into ducts or buildings are secured against moisture or vermin penetration.

4.92 Check cable box gland is the correct size and type for the cable, gland-plate and any single core electrical protection.

4.93 Check cable lug is the correct size for cable core and cable box termination stud and that space between cable box terminations of differing phases and to earth is maintained.

4.94 For HV motors or generators, ensure that the cable box is provided with an explosion diaphragm and replaceable silica gel capsule to absorb penetrating moisture.

4.95 The cables must be disconnected at the equipment before any HV d.c. test. The approved HV clearances in air between equipment terminals, cable ends and earth, at both the far and near equipment cable box terminations, should be applied by:

a. disconnection of the cable lugs from the terminal studs;
b. removal of cable box terminal connecting links, if provided.

HV cable test

Safety precautions as set out in HTM 2021 - 'Electrical safety code for high voltage systems' should be fully applied

4.96 The HV cable test should not be carried out with the cable connected to equipment terminations. Cable box test links, if provided, should be removed. This will allow the cable test to include the cabled termination. Agreement of both the equipment and cable manufacturer should be obtained. This is to ensure that the equipment or cable guarantees are not violated.

4.97 During the time of the HV test, the area where the test is being carried out should be fenced off and guarded by personnel instructed in safety. All other work along the cable route should cease.

Use a 1000 V d.c. (IR) test instrument for circuits above 500 V supply and a 500 V d.c. below 500 V. Maintain the IR test voltage until the megohm reading is steady

4.98 Carry out an IR test between phases and phases to armour (earth), as required for the cable.

4.99 Discharge cable cores to earth after each separate test.

4.100 Apply direct current HV pressure between each set of phases, and each phase to armour, for 15 minutes' duration. BS6622 refers.

4.101 The steady charge d.c. leakage current must be recorded for each test. This should relate to the expected IR and cable length tested.

4.102 Once the tests are completed and the results have been approved, the cable should be fully discharged, terminations applied and cable boxes sealed.

Site HV tests on new buried cables

4.103 The tests are best completed on buried HV cables before final termination at both ends and the ducts being closed or sealed, and before the cable is completely buried. This is to avoid extra recovery complications in the event of a failure in the IR and HV tests or damage done during handling and trench laying.

4.104 The tests are done with the trenched cable covered with only the covering layer of dampened sand. The tests then follow the same procedures given in paragraphs 4.96–4.103. These are summarised as follows:

a. record initial and final IR tests between phases and phases to armour;

b. apply an HV d.c. pressure test to cable for 15 minutes and record the leakage current;

c. fully discharge cable;

d. apply termination and seal cable box.

Integrity of cable outer sheath test

4.105 This test checks the outer sheath of a buried section of cable for any damage during laying, and checks insulation from later and subsequent spot damage caused by corrosion in the cable armour.

4.106 The test can be carried out as follows:

a. prepare to apply a d.c. pressure test between the cable armour and a short driven earthed electrode with the trenched cable covered with dampened sand;

b. apply an IR test;

c. by using a d.c. pressure test set, apply a high voltage for a duration of one minute. This test is required at a variable level of 4 kV d.c. per mm of outer sheath material thickness, maximum 10 kV;

d. repeat IR test before closing duct or back-filling trench.

Use a 1000 V d.c. (IR) test instrument

BS6622 and International Electrotechnical Commission publication 229: 1982, 'Tests on cable over sheaths' refer

All cables must be electrically discharged to earth at the end of each test

5.0 Electrical protection

Test details

General test procedures

5.1 Electrical protection, instrument and metering tests are carried out after completion of all the pre-commissioning inspections, mechanical functional and electrical functional tests.

5.2 After electrical protection tests have been completed and approved, no further disconnection or modification to tested circuits is permitted.

5.3 If any change is made, that electrical protection circuit must be re-tested and re-approved.

5.4 Immediately before a main circuit is energised, the relays associated with the protection circuits must be operationally demonstrated. This is done with the switching device in the isolated position, that is, before insertion into the "service" position.

Test instruments

5.5 High grade instrument/meters for this type of protection testing are required. The meters should have been re-calibrated and certified as reliable by an approved test house, and the certificates presented to the *engineer* for approval.

Relay tests

LV motor thermal overload device

5.6 This test requires a small layout of equipment and should follow the inspection and functional test procedures. The main test procedure is as follows:

a. set thermal relay pointer to motor full load current (FLC) that appears on the nameplate;

b. connect in series all three phases of the overload (O/L) relay;

c. inject 3 x FLC, and measure the time to trip with a stopwatch;

d. compare this time with the O/L current cold curve and determine the percentage time divergence between actual/curve values;

e. allow an extended period of time for the relay to cool, and reset when cooled;

f. allow the thermal relay to stabilise at motor FLC.

5.7 The single phase trip test is carried out as follows:

a. with two phases only in series, inject 2.5 x FLC and measure the time to trip; reset when cooled;

b. record results and compare with O/L current hot curve;

c. check that starter isolator fuse switch and fuse links provide adequate back-up fault protection for the motor cable.

5.8 The stability test is carried as follows: with all three phases of O/L device connected in series, inject motor FLC and observe that the relay remains stable for 15 minutes without operating.

The basic equipment required is:
1. 240 V a.c. variac transformer, capable of delivering three times the simulated motor rated current, through the overload device;
2. multimeter with current and voltage indications;
3. stopwatch.
The following particulars should be noted before the test:

a. relay data, that is, type, serial number and manufacturer;
b. number of thermal elements fitted. Trip level range and setting;
c. overload, current (OLC) curve of thermal relay, current transformers ratio and tapping, full load current (FLC) of motor on nameplate.

Current transformers

5.9 Different types of current transformers (CTs) are provided for differing duties in a switching device: two examples are as follows:

a. for instrument indication, where the indicating meter has a limited deflection above the full scale deflection or maximum current level, it is essential that the CT saturates (the knee point) at just above the maximum current level required;

b. for protection purposes, the CT must not saturate at low levels of current, but must follow a linear output over the full range of overcurrent required for the protection relay to operate. This may be as high as ten times the nominal load current for the circuit load. CTs are identified by a coded system according to BS3938.

5.10 The CT rated secondary current is normally 1 or 5 amperes. The rated current is normally indicated as, say, 500/1 A for 1 ampere secondary, or 500/5 A for 5 ampere secondary. Multi-ratio CTs should be considered where plant output is to be expanded within the ratings of the existing switching devices.

5.11 The 1 ampere CT is more suitable for long runs of secondary wire due to lesser burden than for the 5 ampere CT.

5.12 Secondary S1 and S2 short circuited connections must never be broken when P1/P2 currents flow to avoid induced high voltage in the CT secondary windings.

When testing groups of CTs, all the ones that are not being tested must be short circuited at their S1 and S2 terminals. These short circuits must be removed at the end of each successive test and on completion of the final test

5.13 The linear accuracy of a CT is demonstrated by the magnetisation curve and is shown graphically by the variation in the input secondary voltage plotted against input secondary current while the primary circuit is open circuited.

5.14 Protection CTs used in three-phase overcurrent or differential circuits should have identical magnetisation curves and be of the same manufacture, type or code and:

a. the polarity of the CT must be checked to ensure the correct installation of the secondary winding S1 and S2 terminals in relation to the primary conductor P1 and P2 terminals. This may be confirmed by the "flick test";

b. the ratio of the CT must be confirmed by injecting a small primary current through P1 and P2 and measuring the current at S1 and S2 terminals. This can be confirmed during the stability, balance or sensitivity tests.

CT balance test

5.15 It is essential that a group of CTs forming an overload and earth fault protection circuit do not operate the relay for any balanced input through current. The CTs must be arranged in the correct polarity for the current flow. The schematic diagram provided by the switchgear manufacturer should refer, and:

a. a measured single phase output from a current variac is applied between two phases, on the P2 terminal of the CT;

b. the secondary winding output residual current from the S1 and S2 terminals of the CT is measured in the neutral return loop (all meters, relays and high resistances removed). This neutral circuit residual current should be almost zero in value. If the residual current is twice a single CT output residual current, one of the CTs is incorrectly positioned in relation to P1 and P2

requirements. This process should be repeated to cover the full combination of pairs of CTs, that is, between RY, RB and BY.

Sensitivity of relays

5.16 This test requires the CT's P1 and P2 terminals to be connected to the current variac and the output current from S1 and S2 passed through the operating protection relay, which is usually an earth fault relay located in the CT neutral circuit. The current should be sufficient to activate the relay, normally at 1.5 to 2 times the relay current multiplier setting. Sensitivity test for relays should initially be verified by primary injection into the circuit where the current flow is known, and in relation to the P1 and P2 nomenclature of the CTs marked on the schematic diagram. An operating flow of primary current should cause the protection relay to operate at the set current multiplier.

Stability of relays

5.17 This test demonstrates the correct functioning of differential relay protection circuits in a zone of circuits enclosed by a perimeter of two CTs per phase. The primary current should be at full load to ensure that any characteristic differences in the two perimeter CTs is not sufficient to be detected in error as a lack of balance in the differential circuit. To check the sensitivity of one CT, the primary P1 and P2 should be short circuited, and test current increased to operate the test relay.

5.18 The arrangement of the P1, P2 and CT positions should be in relation to the designated direction of current flow. For a differential scheme, the P1 sides should face inwards towards the zone protected.

5.19 With generators, the ratios of CTs will be equal on either end of the phase/neutral termination of the stator winding.

5.20 For transformers, the ratios will be dictated by the transformer winding ratio/connections to achieve equivalent secondary currents. For the CT secondary protection circuit, the 180° change of phase direction on transformation, plus the phase shift caused by the delta/star primary main circuit connections, must be corrected.

5.21 Reversal of the CT primary P1 and P2 positions or S1 and S2 terminations will correct phase reversal. The CT must be re-labelled. Phase shift due to delta/star connections must be offset by CTs of suitable ratio arranged/connected at each three-phase assembly of CTs into a star-delta in-phase corrective connection.

5.22 The secondary currents and voltages in the respective phases of a delta-star transformer undergo a magnitude change of $\sqrt{3}$. This magnitude difference must be corrected by interposing current transformers of $1:\sqrt{3}$ ratio.

5.23 Possible errors on the circuit diagram or in the actual secondary wiring connections are:

a. CTs star connected on wrong side;

b. wrong delta connection used on current transformers;

c. pilot wires between CTs crossed over.

Secondary injection test equipment

Test plugs

5.24 It is common practice to insert a multi-pin test plug into the relay circuit to facilitate connections of test equipment without disturbing relay circuit wiring.

5.25 By the use of a test plug, the operating and alarm currents of a relay can be injected or measured without disturbing the CT circuit connections. The test plug pins are electrically split; they are inserted between the relay case spring-loaded contacts and short circuited by small links. The spring contacts connect the relay externally to the CT's trip circuits and alarms.

Test variac transformer

5.26 The relay input current is obtained from a purpose-built test variac. This variac should:

a. have sufficient output to replace the CT secondary 1 A and 5 A rating levels (that is, ten times), for the short periods necessary to cause rapid relay operation;

b. be free of harmonic current distortion to the input current;

c. have the input test current flow/time measured to an accuracy of 0.01 second;

d. have metering instruments, control switches and connections to match CT output impedances;

e. be transportable, manoeuvrable at site locations and in switchrooms;

f. have a multimeter capable of accurately indicating 10 A a.c.

Protection relay test criteria

Test arrangements

5.27 The arrangements for the test of the protection relays requires adequate planning because the protective gear is solely concerned with fault conditions.

5.28 Protective relay testing is divided into three stages:

a. factory tests;

b. pre-commissioning tests;

c. periodic maintenance tests.

5.29 The first two stages certify the performance of the protective gear during its development, manufacture and performance in its operational environment. The last stage, when properly planned and carried out, ensures that the relay performance is maintained throughout the life of the protection gear and electrical equipment being protected.

Primary injection test

5.30 The main purpose of this test is to determine the stability of certain types of protective gear under conditions that would prevail in service. This method is also a comprehensive demonstration of the protection, alarm and indication elements provided in a protective gear design.

5.31 The essential requirement of all forms of balanced protection gear is stability under the most extreme through fault current conditions. Under such a fault condition, the CT's primary circuit will be subjected to a sudden rise in current of distorted waveform.

5.32 The growth in primary current will require a corresponding rise in secondary current in the CT. With two differentially connected CTs, any variation in the magnetising characteristic will be shown as an inequality of output and may cause imbalance and incorrect operation of the protective gear.

5.33 The protective systems which may require primary injection tests are:

a. balanced and restricted earth fault protection;

b. bus-bar protection;

c. generator differential protection;

d. pilot wire protection;

e. phase comparison;

f. circuit breaker protection incorporating an earth fault protection element.

Secondary injection test

5.34 Equipment and necessary tests are generally stated in the manufacturer's manuals. These are:

a. a test plug is used in the relay circuits where continuity is maintained by small links inserted into the plug sockets. These short-circuit the split connector pins. Alternatively the sockets may be used to provide a test supply of relay operating current from a test set;

b. portable test equipment can be connected into the relay circuit through the test plug to inject a simulated level of current that would, in an operational circuit, be provided by the CTs. The level of current can be pre-set in multiples of the CT rated current of 1 A or 5 A, then switched into the relay circuit for final adjustment of relay current;

c. when the relay is initiated and the timer started, it will automatically switch off when the relay is tripped to indicate the time of operation.

Scope of relay testing

5.35 Portable test equipment can be applied to the following protection system:

a. overcurrent and earth fault relays;

b. differential relays;

c. pilot wire operated relays;

d. negative phase sequence relays;

e. distance impedance relays;

f. bus-bar protection relays.

Tripping and alarm tests

5.36 During the secondary injection tests, the relay trip and alarm circuits are rendered inoperative by removal of the battery supply fuses, solid links and trip links, etc. This would prevent unnecessary alarms sounding and switch operations. It is essential that on completion of secondary relay testing, all switching device trips, controls, indications and alarms are given a final check for operation.

5.37 The test checks can be performed by operating the relay or trip test buttons to ensure that the correct switching device is operated and the correct flag or signal is annunciated, where the indications are required, at the local or remote control station.

5.38 Where installed, the trip circuit supervision should be checked regularly for operation.

6.0 Earthing

Power systems

General earthing considerations

6.1 To ensure rapid disconnection of faulty electrical circuits, the site earthing facilities must be considered in relation to the particular plant fault current rating and protection requirement.

6.2 All earthing conductors should be visually inspected at six-monthly intervals and subjected annually to a heavy current injection. HTM 2021 – 'Electrical safety code for high voltage systems' refers.

Fault current paths

6.3 The fault current path is defined as the path of minimum impedance starting and ending at the point of the fault. This may take two basic forms:

a. earth fault loop impedance, which is the sum of the impedances starting from the point of fault to the exposed conductive part, the cable earth cores and/or protective conductor, the transformer star point and phase winding, and finally the cable phase conductor returning to the point of fault;

b. earth electrode ground impedance, which is the sum of the impedances starting from the point of fault passing through the building extraneous conductive parts, if present, through the ground to the earth electrode on to the transformer star point and phase winding, and finally the cable phase conductor returning back to the point of fault.

6.4 Where power equipment is supplied by armoured or screened cables, the earth electrode ground impedance may be short circuited by the earth fault loop impedance. Cable armour must not be relied upon as the only earth fault current path.

6.5 An additional conducting path should be present to ensure that the frame of the equipment is solidly connected to earth.

6.6 Equipment with rated currents of 100+ amperes should be connected at the main frame by a 75 mm^2 copper protective conductor directly to the main earth system.

Requirements for an earthed system

6.7 To provide a path to earth for fault currents.

6.8 To eliminate potential dangers to personnel.

6.9 To ensure that all building metal cladding or parts of electrical equipment are connected to earth by a group of low resistance earth electrodes.

6.10 To provide a reference voltage for the correct operation of protective gear to sense and disconnect earth fault currents.

6.11 To allow the passage of sufficient earth current to operate rapidly and safely the largest capacity fuse link in the system.

Recommendations

6.12 Paths of currents in the ground must be of sufficiently low resistance to allow the passage of lightning discharge currents or fault currents from the point of supply to earth. This would prevent the rise of dangerous voltages occurring between any two points that can be touched by one person.

6.13 The main earth system should be linked below ground level to the lightning earth system.

Electronic equipment

6.14 All electronic equipment must be earthed. Electronic equipment for clinical or computer use can be very sensitive to interference caused by fluctuating changes in the volt drop to earth. These occur when they share a protective conductor connected to other items of electrical equipment. A separate earth system to eliminate this interference is recommended. HTM 2014 – 'Abatement of electrical interference' refers.

High frequency heating equipment (industrial and medical diathermy)

6.15 Special care should be taken in high frequency heating operations to ensure that the earth system has a negligible reactance at the frequency of operation.

Earth electrodes

Location of main earth

6.16 The extent of the earth electrode system for the electrical supply must be established early in the construction process. To obtain a stable 2 ohm resistance, the location of the earthing electrode should be selected after repeated ground tests made over an extended period of weather change. Once a location has been agreed with the *engineer*, it should be marked on the site drawings before structural layout details are drawn. Tests should be taken regularly to determine the effects of site foundations and drainage upon the ground moisture and resistivity (ohm – m^3).

6.17 Resistivity is defined as the ohmic resistance between the two opposite faces of a metre cube of soil. The value of electrode resistance is controlled by:

a. nature of the ground;

b. the density of the earth current flowing through an electrode;

c. the number of electrodes used;

d. the depth of electrode ground insertion.

Earth resistance measurement

6.18 Two methods are generally used:

a. operating a proprietary earth test instrument to the manufacturer's instructions;

b. using a mains supply transformer with controlled secondary output (usually used at large sites).

6.19 In both cases an earth electrode is connected by a surface cable to two driven test earth electrodes where the nearer is placed at approximately half the radius of the farther from the earth electrode.

A high impedance voltmeter must be used (in excess of 200 ohms per volt) to prevent shunting of the ground resistance.

6.20 A test output current is circulated between the earth electrode and the farther test electrode and the voltage drop is recorded between the earth electrode and the nearer test electrode to give the resistance value. The radius of the nearer test electrode should be varied around the half radius position to ensure that a steady value has been obtained in the voltage drop reading.

Types of electrode

6.21 There are several types of electrode used. One important consideration is the ground structure and the presence of corrosive electrolytes in the ground soil material. The presence of these electrolytes greatly reduce the life of an electrode. Alternatively, the use of chemicals to lower the soil resistivity is not recommended, as this remedy is not permanent.

6.22 Copper rods, or steel rods encased by a thin copper sleeve, are driven several metres into the ground. Driving copper rods into rock can be very difficult. Examples of different solutions are as follows:

a. in difficult cases, a bore hole should be drilled into the ground and the rod dropped into the hole, and the annulus space then filled with a conductive slurry. In exceptional cases, the bottom of the bore hole may require blasting with explosives to produce ground fissures before the slurry is admitted;

b. cast iron plates or pipes can be buried down to a 3 metre depth. The cast iron parts must be interconnected by waterproof sheathed copper straps or cable. The terminal connections must be suitably protected against metal-to-metal corrosion or ground corrosion by the use of a waterproof tape or compound.

6.23 The use of coke breeze as a contact matrix between the cast iron is not recommended, as the coke contains sulphurous compounds which can accelerate electrode metal corrosion.

Protective conductors

6.24 Copper or aluminium are both satisfactory metals to use as protective conductors. Aluminium, however, presents the least preferred option as it is less easily prepared and jointed than copper, occupies more volume and requires larger fitments.

6.25 Bare copper or aluminium conductors should not be buried in the ground without a PVC protective oversheath. All joints and connections should be wrapped in bitumastic compound or serviceable waterproof woven tape.

6.26 The sizes of earthing conductors which are suitable for switchgear of standard rating is shown in Table 1.

Switchgear: 3-second rating (kA)	Size of copper conductor cross-sectional area mm^2	Dimensions mm x mm
Not exceeding 14	75	25 x 3
Not exceeding 22	150	25 x 6
Not exceeding 30	228	38 x 6
Not exceeding 44	300	50 x 6

Table 1 Earthing conductor sizes

Screened rooms

6.27 If proper planning of hospital departments is carried out, the need for screened rooms is eliminated. These rooms, if constructed, would be used for special treatment/data locations. They are expensive to construct and should be identified at an early stage and advised to the architect.

6.28 All electrical/electronic equipment in such an area should be manufactured to the appropriate standards in respect of their electromagnetic compatibility.

6.29 Where confidential data is processed, all power supplies, control, telephone and data cable should be electromagnetically screened and electrically filtered to prevent radiated or mains borne interference. HTM 2014 – 'Abatement of electrical interference' refers.

6.30 A separate earthing system may be necessary, having a short direct route to earth.

Battery earthing systems

6.31 It is recommended that central battery systems should be earthed. Where external telephone systems are provided by others, the telephone earth system equipment will be installed separately by that contractor.

6.32 Battery supplies can cause undesirable corrosion effects in alarm and control circuits activated by the type of polarity connection to the earth system.

1. 50 V batteries should be connected with the positive pole connected directly to earth. This voltage is used generally for telephone and equipment alarm systems.
2. 110 V and 240 V battery supplies should have their positive terminals earthed through a potential dividing instrument designed in such a manner that an earth leakage current flows and activates an alarm when an insulation failure in the circuit is detected. These voltages are used generally for central sources of emergency lighting and control supplies on large switchboards

7.0 Power and lighting circuits

Inspection and testing

General

7.1 The purpose of inspection and pre-commissioning is to ensure that the requirements of the contract and the guidance given in the IEE Wiring Regulations are met in the completion of an installation.

7.2 During all pre-commissioning tests on LV circuits, it is essential that due regard is given to the statutory requirements of the Electricity at Work Regulations 1989 and the guidance of HTM 2020 – 'Electrical safety code for low voltage systems'.

Identification of circuits and notices

7.3 All distribution boards (DBs) should be correctly and uniformly identified and detailed on a schematic diagram. Where applicable, all DB equipment must display clear numbers and letters on both the front and the inner surfaces.

7.4 All cables entering a DB must be permanently numbered at both ends, and those numbers recorded in the cables schedule with the rating and material details.

Inspection of distribution boards

7.5 All cables entering a DB should be properly glanded and the DB sealed to protect them against vermin.

7.6 Locations of DBs should be suitable for extended work and provide adequate work space.

7.7 All wiring should be neatly arranged and loomed within the DB and all cores identified.

7.8 The DB inspection cover must display, in an accessible manner, a description of all the circuits supplied by or connected to fuse holders or MCBs within the DB.

7.9 Fuse links and MCBs must be correctly sized for the rating of electrical equipment and cables.

Sequence of tests

7.10 It is recommended that the test procedures follow a logical routine and that any incorrect installation be identified at the earliest possible stage in the test. The obvious and easily corrected errors should be recorded for immediate action. The following is a guide to test procedures:

a. ring mains and radial circuit continuity;

b. protective earth conductor continuity;

c. measurement of the circuit's IR;

d. check live and neutral polarities at the load terminals and single phase and/or three-phase sequence of supply at the DB intake;

e. measure the earth fault loop impedance for each circuit to ensure adequate discrimination;

f. where RCDs are installed, check the operation;

g. record tests and observation on the approved record sheets.

Ring main continuity and measurement test

*Before starting the test, ensure that all safety precautions are observed and that both the L and N circuits are isolated and made **dead***

7.11 Method 1:

a. zero the resistance of leads at the test meter;

b. measure the loop resistance of the ring main protective conductor at the DB;

c. measure the resistance between the ring main protective conductor and the earth on the mid-positioned socket-outlet;

d. the resistance of test b should be approximately four times that of test c;

e. repeat b and c for the L and N conductors of the circuit.

7.12 Method 2 applied at a common point of test:

a. zero the resistance of leads at the test meter;

b. measure the loop resistance of the ring main protective conductor at the DB;

c. repeat b for L and N circuits;

d. measure the loop resistance, at the DB, between the disconnected L and N circuit wires while the mid-positioned socket-outlet L and N terminals are interconnected;

e. the resistance measured should be approximately half of the resistance of c;

f. measure the loop resistance, at the DB, between the twisted L and circuit protective conductor wires while the mid-positioned socket-outlet L and earth terminals are interconnected;

g. the resistance measured should be approximately one-quarter of the loop resistance of the circuit protective conductor and L conductor circuit resistance obtained in (b) and (c).

Circuit protective conductor continuity test

*Before starting the test ensure that all safety precautions are observed, and that the circuit has been isolated and made **dead***

7.13 Interconnect the circuit protective conductor and N bars within the DB. Measure the resistance between the earth and N terminals at each socket-outlet.

High current test of a circuit protective conductor

7.14 Where a steel conduit or enclosure forms part of the circuit of a protective conductor, the circuit should be checked by a high current injection test of 1.5 times the circuit normal rated current, but not greater than 25 amperes.

7.15 A current injected from a controlled source connected between the DB protective conductor bar and the socket-outlet earth terminal should be applied.

A continuity test should be carried out prior to commencing this test. This ensures that no excessive voltages will be generated by the controlled current source.

Polarity

It is most essential that the live, neutral and protective conductor of a radial or ring circuit be connected to the correct socket-outlet terminals

7.16 To test for live circuit polarity, the following is carried out:

a. connect a continuity meter between the live terminal in the DB and the L terminals in each socket-outlet of the installation;

The circuit must be isolated and made **dead**

5 a correct terminal block will measure a low circuit resistance, connected, or incorrect connection will read an open circuit

Insulation tests

Circuit tests

1 The circuit must be isolated and made **dead**
2 These tests ensure that a high insulation resistance exists between the live, neutral and the protective conductor connections. A value of at least 1 Megaohm is normally expected, from a 240 V system, between the recommended socket-outlet L terminal and the N or earth terminals.

The circuit must be isolated and made **dead**

Use a 500 V d.c. test instrument

The circuit must be isolated and made **dead**

Use a 500 V d.c. test instrument

7.17 Stages of the circuit insulation resistance test

a with the LE isolating switch closed, connect the LE measuring mega L and N terminals together,

b measure the insulation resistance between the connected L and N terminals and the LE protective conductor bar. The measured IR should not be less than 1 Megaohm,

c repeat the test L and N with earth terminals connected

7.18 Transformer circuit insulation test

a measure the insulation resistance between each secondary phase and the other two phases, while the neutral conductor and the protective conductor are unused,

b isolate the neutral conductor and measure the insulation resistance between the neutral and the protective conductor,

c the measured insulation resistance should not be less than 1 Megaohm.

Earth circuit tests

General

7.19 There are two main tests required. These are the earth electrode resistance test and the earth loop impedance test.

7.20 Electrode resistance This test measures the resistivity in ohm-metres offered by the surrounding ground mass to the passage of an electrical current from a driven earth reference electrode. Where more than one earth electrode is driven, each should be measured separately.

7.21 Earth loop impedance The earth loop impedance test measures the impedance to the flow of current from the live terminal into the protective conductor, the main cable armour, through the transformer neutral point and winding and back by the phase conductor to the live terminal. The following refers:

a earth electrode resistivity test:

(i) the main earth electrode bank must be separated at the main earth terminal bar into two temporary sub-banks, one for continued operation and the other for test purposes,

(ii) a proprietary earth electrode tester is connected between the main earth sub-bank test terminal bar and two driven test electrodes at equally spaced distances from the earth electrode bank,

(iii) for a stable reading, adjust the nearer test electrode position. The measured resistance obtained will be in ohms,

(iv) for an instrument giving only a resistivity ohm-metre reading, the resistance of an electrode driven into untreated soil is given by the equation:

$$\text{resistance} = \frac{P}{275L} \log_{10} \frac{(400L)}{d} \text{ ohms}$$

where p = resistivity in ohm-metres;
L = length of rod in metres;
d = diameter of the rod in metres, where L is much greater than d;

(v) a 3.6 metre long, 12 mm diameter electrode is capable of carrying a current of 50 to 100 amps where the resistivity is 50 to 200 ohm-metres;

b. earth loop impedance test:

(i) this test uses a proprietary phase-earth loop test instrument and can be carried out from an a.c. socket-outlet position while the circuit is **live**;

(ii) the instrument injects a large current pulse of short time duration into the loop circuit to indicate the earth loop impedance. This current is of insufficient magnitude to activate the protection.

8.0 Sample test sheets

General

These sample test sheets are presented as examples only. The tests and recorded results for various items of electrical equipment should be mutually agreed between the *engineer* and the contractor, within the restraints of the contract document.

Plant item:	Completed		
Identification/location:	Incomplete		
Contractor:	Pc address – file		
Manufacturer:			
Serial No:			

No	Activity	Witnessed		
		Engineer (HCP)	Contractor	Date

Witnessed	Engineer (HCP)	Contractor	Date	
Print name and sign				Sheet 1 of

SAMPLE

8.1

Plant item: Fixed panels and switchboard inspection	Completed	
Identification/location:	Incomplete	
Contractor:	Pc address – file	
Manufacturer:		
Serial No:		

No	Activity	Witnessed		
		Engineer (HCP)	Contractor	Date
1	Check drawing for any damage or incomplete work.			
2	Check all labels, warning symbols, switchboard and circuit identification labels are correct.			
3	Check switchboard is fixed and mounted correctly.			
4	Check switchboard protective earth conductors are connected to the main earth system.			
5	Check terminations, lugs and blocks for tightness.			
6	Check VT and CT compartments assembled correctly.			
7	Check shutter linkage and the locking facilities.			
8	Rack all devices into cubicle service position; note: shutters must have smooth, easy movement.			
9	Check all bus-bar bolted joints with a set torque spanner, and inspect joint contact surfaces. Bolts sizes (mm) . . . . . . Specified torque setting (nm)			
10	Isolate VT, remove fuselinks of voltmeter and CTs Measure: (i) IR vt. py./sy. (ii) IR CT sys. (iii) IR bus-bar and circuit bar phases.			
11	Measure total conductance of HV bus-bar phases along the switchboard, by ohmmeter measurement: e.g. by: a. between adjacent cubicle bus-bar phase spouts (BS) b. between circuit spout (CS) and cable box (BT) Note: Estimate resistance, from 1.0 m of conductor.			

Between spouts	Red phase	Yellow phase	Blue phase	Res.
BS1 and 2				micro ohms
BS2 and 3				micro ohms
BS3 and 4				micro ohms
1CS and 1BT				micro ohms
2CS and 2BT				micro ohms
3CS and 3BT				micro ohms
4CS and 4BT				micro ohms

Witnessed	Engineer (HCP)	Contractor	Date	Sheet 1 of 1
Print name and sign				

8.2

Plant item: HV pressure test – switchboards	Completed	
Identification/location:	Incomplete	
Contractor:	Pc address – file	
Manufacturer:		
Serial No:		

No	Activity	Witnessed		Date
		Engineer (HCP)	Contractor	
1	Before HV test, ensure all covers and fittings are replaced and are secure.			
2	Check: (i) all instrument fuselinks removed; (ii) VT isolated and CT fuselinks removed; (iii) IR test bus-bars before and after pressure test. Megaohm values: R - Y . . ./. . ., Y - B . . ./. . ., B - R . . ./. . . R - N . . ./. . ., Y - N . . ./. . ., B - N . . ./. . . R - E . . ./. . ., Y - E . . ./. . ., B - E . . ./. . .			
3	Ensure the Safety Rules are strictly followed, according to HTM 2021 (HV).			
4	Pressure test bus-bars – as directed by contract, e.g. 0.415 kV system – 2kV a.c. for one minute 3.3 kV system – 8.6 kV a.c. for one minute 11 kV system – 24 kV a.c. for one minute			
	Voltage . . . . . kV / Humidity . . . . . % / Temperature . . . . °C			
	Phase leakage current: R – Y . . . . . .mA; Y – E . . . . . .mA; B – E . . . . . .mA			
	Phase leakage current: R – N . . . . . .mA; R – N . . . . . .mA; B – N . . . . . .mA			
	Phase leakage current: R – E . . . . . .mA; Y – E . . . . . .mA; B – E . . . . . .mA			
5	Check IR of close, open and control circuits.			
	Remarks: Switchboards in site locations should be HV tested and energised as soon as possible, as security against bus-bar copper theft.			

Witnessed	Engineer (HCP)	Contractor	Date	
Print name and sign				Sheet 1 of 1

8.3

Plant item: Switching devices – mechanical test		Completed	
Identification/location:		Incomplete	
Contractor:		Pc address – file	
Manufacturer:			
Serial No:			

No	Activity	Witnessed		Date
		Engineer (HCP)	Contractor	
1	Inspect switch device for damage and cleanliness.			
2	Check all components are assembled and tightened as required in the general arrangement drawing.			
3	Check all device labels against switch schedule.			
4	Check device fixed/moving contact alignments are correct to manufacturer's recommendations.			
5	Carry out manual slow and spring close operations, then trip circuit breaker or device by mech. PB.			
6	Establish close, open and control supplies.			
7	Measure resistance across each circuit breaker closed phase contacts at (CB), with ohmmeter. 1CB | | | micro ohms 2CB | | | micro ohms 3CB | | | micro ohms 4CB | | | micro ohms			
8	Circuit earth and isolated arrangements Ensure the cubicle bus-bar shutter door mechanism is locked shut. The circuit shutters must be unlocked for circuit earth test.			
9	(i) at cubicle: rack-in device to earth position, close by electrical operation at the local and remote controls; (ii) repeat for isolated position; (iii) check operation of any circuit key interlocks.			
10	Check movement of auxiliary switches and mechanical semaphores, at both earth and isolated positions.			

Witnessed	Engineer (HCP)	Contractor	Date	Sheet 1 of 1
Print name and sign				

SAMPLE

Plant item: Switching devices – electrical test	Completed	
Identification/location:	Incomplete	
Contractor:	Pc address – file	
Manufacturer:		
Serial No:		

No	Activity	Witnessed		
		Engineer (HCP)	Contractor	Date
1	Ensure cubicle bus-bar/circuit shutter door mechanisms are locked shut, if switchboard has been energised.			
2	Carry out IR test between device open main contacts, and when closed, between phases and frame earth. Values: R . . . / . . . / . . . /Y . . . / . . . / . . ./B . . . / . . . / . . . /Megaohms			
3	HV pressure test device – as directed by contract. e.g. 3.3 kV system – 8.6 kV for one minute. 11 kV system – 24 kV for one minute. kilovolts (kV) (i) between phases, with the circuit breaker closed; RY – B kV / RB – Y kV / BY – R kV (ii) between phases and frame earth; RY – BE kV / RB – YE kV / BY – RE kV (iii) across open contacts. R – Y kV / R – B kV / B – Y kV Values: R . . . / . . . / . . . /Y . . . / . . . / . . ./B . . . / . . . / . . . /Megaohms			
4	Rack the device into the cubicle isolated position, for the close/open operational tests.			
5	Check at local control: close and trip of device at the rated battery voltage: minimum of ten operations.			
6	Check the operation of close and trip at 80% of the rated applied close battery voltage.			
7	Check operation of trip mechanism at 50% of the rated applied trip battery voltage.			
8	Check time of closing mechanism operating spring to recharge, at 80% of rated applied voltage.			
9	Emergency generator set circuit breaker sequence test to HTM 2011, as applicable.			

Witnessed	Engineer (HCP)	Contractor	Date	
Print name and sign				Sheet 1 of 1

SAMPLE

8.5

Plant item: Transformer – mechanical test		Completed	
Identification/location:		Incomplete	
Contractor:		Pc address – file	
Manufacturer:			
Serial No:			

No	Activity	Witnessed		
		Engineer (HCP)	Contractor	Date
1	Check drawing: general inspection for damage and completeness.			
2	Check all components fitted to general arrangements.			
3	Prove tightness of all fastenings.			
4	Check all labelling to transformer schedule.			
5	Check transformer correctly positioned in bay for cable box entries/bushing connections.			
6	Check colour of dessicator crystals is blue (conservator type).			
7	State type of coolant in tank.			
8	Check if transformer filled with oil/fluid to operating level – yes/no.			
9	Check for any oil/fluid leaks.			
10	Check if cable box details agree with cable details and requirements.			
11	Check location of loose CTs, if provided, and method of connection in cable box or to star-point neutral.			
12	Check position of transformer earth lug and connection to main earth system.			
13	Prelim. d.c. IR using megger and res. check of winding. HV – R – Y: M, ohms, Y – B: M, ohms, B – R M ohms LV – r – y: M, ohm, y – b: M, ohm, b – r: M ohm HV/LV – R – r: M, Y – y: M, B – b: M RYB – E: M, ryb – E: M			

Witnessed	Engineer (HCP)	Contractor	Date	
Print name and sign				Sheet 1 of 1

SAMPLE

8.6.1

Plant item: Transformer – electrical test		Completed	
Identification/location:		Incomplete	
Contractor:		Pc address – file	
Manufacturer:			
Serial No:			

No	Activity	Witnessed		
		Engineer (HCP)	Contractor	Date
1	Check marshalling box wiring connections at termination blocks for tightness and correct labelling/ferrulling.			
2	Check IR of control wiring using megger: (i) marshalling box control wiring; (ii) Buchholz; (iii) temperature indicators: oil/fluid core			
3	Temperature indicators set at oil/fluid °C alarm °C trip core °C alarm °C trip			
4	Fill transformer with oil/fluid to operating level on conservators, if required. (New transformer oil/fluid to be used. Each barrel to be individually sampled and certified to BS148 before putting into transformer tank.)			
5	Check IR of core insulation to earth before link is covered with oil/fluid, during fill operation.			
6	Check IR of oil/fluid filled transformer. HV – R – Y: M, Y – B: M, B – R: M LV – r – y: M, y – b: M, b – r: M HV/LV – R – r: M, Y – y: M, B – b: M RYB – E: M, ryb – E: M, N – E: M			

Witnessed	Engineer (HCP)	Contractor	Date	
Print name and sign				Sheet 1 of 3

SAMPLE

Plant item: Transformer – electrical test	Completed	
Identification/location:	Incomplete	
Contractor:	Pc address – file	
Manufacturer:		
Serial No:		

No	Activity	Witnessed		Date
		Engineer (HCP)	Contractor	
7	Winding ratios at each off-load tap position, and the transformer vector group. (i) apply 415V 3-phase a.c. to HV winding terminals, and interconnect: R – HV phase to R – LV phase. (ii) winding ratio: HV: R – Y: v, Y – B: v, B – R: v. LV: r – y: v, y – b: v, b – r: v. Tap position 1: v, v, v. 2: v, v, v. 3: v, v, v. 4: v, v, v. 5: v, v, v. 6: v, v, v. 7: v, v, v. 8: v, v, v. 9: v, v, v. 10: v, v, v. 11: v, v, v. (iii) vector group: R – Y v, Y – B v, B – R v. r – y v, y – b v, b – r v. R – r v, Y – y v, B – b v. B – y v, Y – b v,			
8	Check trip/alarms supplies voltages: (i) at circuit breaker (as provided); (ii) at transformer: (a) Bucholz (b) oil/fluid temperature (c) Tank pressure (d) cooling fans running			
9	Check IR of tap changer control panel with megger (where provided).			

Witnessed	Engineer (HCP)	Contractor	Date	Sheet 2 of 3
Print name and sign				

SAMPLE

8.6.3

Plant item: Transformer – electrical test	Completed	
Identification/location:	Incomplete	
Contractor:	Pc address – file	
Manufacturer:		
Serial No:		

No	Activity	Witnessed		Date
		Engineer (HCP)	Contractor	
10	Check IR of transformer cooling fan motors, and cable termination (where provided).			
11	Check transformer cooling fan motor electrical function in local/remote/auto modes.			
12	Check transformer cooling fan motor overload/time by 3-phase and single phase injection.			
13	Check cooling fan motor rotation.			
14	Check the three phases to each winding of the transformer are not cross-connected between the near or the far terminations.			
15	Final bay check before energising transformer: (a) take final oil samples for analysis and certification, one from the tank drain valves and one from the Buchholz relay drain cocks; (b) check IR of the HV and LV windings; (c) check operation of all protection trips and alarms at initiating devices and control section; (d) check cooling fan controls are operational; (e) cable box and bushing connections tight, oil leak free and secure; (f) transformer bay gate locked shut.			

Witnessed	Engineer (HCP)	Contractor	Date	Sheet 3 of 3
Print name and sign				

8.7

Plant item: LV contactor gear	Completed	
Identification/location:	Incomplete	
Contractor:	Pc address – file	
Manufacturer:		
Serial No:		

No	Activity	Witnessed		Date
		Engineer (HCP)	Contractor	
1	Check all components fitted to general assembly drawing.			
2	Check tightness of all fastenings.			
3	Check labelling and warning symbols to relevant diagram.			
4	Check earth connection to main earth system.			
5	Check all flash guards and contacts aligned.			
6	Check mechanical operation and interlocks.			
7	*IR check 415V circuit using megger.			

R – Y	M	R – B	M	Y – B	M
R – E	M	B – E	M	B – E	M

*Short circuit/disconnect all electronic equipment which could be damaged before megger testing.

8	D.c. operated contactors – check that contactor operates at: (i) 80% of rated voltage (close); (ii) 50% of rated voltage (trip).				
9	A.c. operated contactors – check that contactor operates at: (i) 85% of rated voltage and remains closed down to 75% of rated voltage.				
10	Operate contactor five times at normal operating voltage.				
11	Check current ratings of all fuselinks.				

Witnessed	Engineer (HCP)	Contractor	Date	
Print name and sign				Sheet 1 of 1

Plant item: Motor thermal overload device: overload injection	Completed	
Identification/location:	Incomplete	
Contractor:	Pc address – file	
Manufacturer:		
Serial No:		

No	Activity	Witnessed		
		Engineer (HCP)	Contractor	Date
	Relay data Type ..... Serial no. ..... Element fitted..... Circuit FLC..... CT ratio ..... CT tapping ..... Trip level setting..... Phases..... Note: trip level setting will normally be circuit or motor full load current (FLC).			
1	With all three phases connected in series, check starting curve (cold), measure time to trip at three times FLC. Time from curve ..... sec. Time measured..... sec. Time measured to be within..... % of optimum characteristic.			
2	Reduce current to zero and ensure that relay will reset when cold.			
3	Single-phasing check: maintain at circuit FLC and allow relay to reach a stable state. Inject 2.5 times FLC level setting through left and centre elements in series. Repeat through centre and right elements in series. Measure times to trip. LH and centre ..... sec. RH and centre..... sec. Time measured to be within..... % of manufacturer's specified time.			
4	Stability check: carry out stability test at FLC level setting for 15 minutes. All temporary connections and shorts removed on completion.			

Witnessed	Engineer (HCP)	Contractor	Date	
Print name and sign				Sheet 1 of 1

8.9

Plant item: Functional and IR test – secondary wiring	Completed	
Identification/location:	Incomplete	
Contractor:	Pc address – file	
Manufacturer:		
Serial No:		

Activity				
Schematic diagram number	Circuit description	Core numbers involved	Results	
			Function check	IR check

Notes of guidance for testers:

The tester must systematically check through all circuits to the approved schematic diagram proving the function of components in the equipment schedule, and also carry out negative checks.

The tester must carry out a final check of connections, and ensure all fuses and solid links, earthing and wiring termination, dust covers, shrouds and all test leads, connections, shorts, etc have been removed from the panels before establishing the permanent supply voltage.

Witnessed	HCP	Contractor	Date	
Print name and sign				Sheet 1 of 1

SAMPLE

8.10

Plant item: Secondary wiring injection test (tripping and auxiliary tripping relays)	Complete	
Identification/location:	Incomplete	
Contractor: Manufacturer:	Pc address – file	

Activity								
Function and location	Make, type and model number	Serial no	Mech. insp.	Minimum operating volts/ amps (not normally applicable to single auxiliary relays) (note 2) Operate coil	Reset coil	Operate time (note 1)	Reset time (note 1)	Nominal rating volts/amps

Note 1 Operating and reset times to be checked at rated volts for slugged relays and timing relays.
Note 2 An overall minimum operating voltage test should be applied to all relay systems to eliminate possibility of spurious operating conditions.

Remarks:

Witnessed	HCP	Contractor	Date	Sheet 1 of 1
Print name and sign				

SAMPLE

8.11

Plant item: Batteries		Completed	
Identification/location:		Incomplete	
Contractor:		Pc address – file	
Manufacturer:			
Serial No:			

No	Activity	Witnessed		Date
		Engineer (HCP)	Contractor	
	Inspection of battery installation prior to initial charge			
1	Check that battery/battery room labelling/identification is complete and correct.			
2	Check that equipment is undamaged, correctly installed and complete.			
3	Disconnect all solid state electronic monitoring or protection devices during IR tests.			
4	Check insulation resistance to earth of battery using a d.c. megger (battery disconnected). Connections/bus-bars: Positive to earth.....Mohms Negative to earth.....Mohms			
5	Check intercell connections are tight and joints greased. *Any damage to paintwork on battery support steelwork must be rectified prior to filling cells.			
6	Fill cells to correct level with electrolyte.			
7	Record cell voltages and s.g.'s (sheet 2).			
8	Check filler caps are secure and vent holes free.			
9	Check bus-bars are shrouded, secured and identified for polarity.			
10	Check wall bushings are secure, sound and clean.			
11	Link box identified, lockable and correct colour (red).			
12	Check battery link box fuse rating correct.			

Witnessed	Engineer (HCP)	Contractor	Date	
Print name and sign				Sheet 1 of 1

8.12

Plant item: Battery charger – charge test		Completed	
Identification/location:		Incomplete	
Contractor:		Pc address – file	
Manufacturer:			
Serial No:			

No	Activity	Witnessed		
		Engineer (HCP)	Contractor	Date
1	Operate charger to fully charge battery.			
2	Connect load equipment up to 50% of charger rating. With charger switched off, check that battery discharges correctly into load (instrument polarities correct, etc). Check that low voltage alarm operates.			
3	Switch charger on to "float" and check charger attains fully rated output. Check "current limit" feature operates.			
4	Switch charger to "boost" (where provided), and with load still connected, check that full rated output is obtainable. (This test must not be unattended.) Note: Boost current control should be set to maximum. Maximum current may only persist for a short time before a current reduction occurs.			
5	Switch charger to "float" and with load still connected check that d.c. rated voltage is within specification for rated a.c. voltage.			

Witnessed	Engineer (HCP)	Contractor	Date	
Print name and sign				Sheet 1 of 1

8.13

Plant item: Battery discharge test	Completed	
Identification/location:	Incomplete	
Contractor:	Pc address – file	
Manufacturer:		

Activity

Ampere-hours .....
Volts at commence of test .....
Ambient temp. °C

Ten-hour test rate .....
Volts at completion.....
Ambient temp. °C

Hours of discharge

Cell no	Init. spg	.25 v	1 v	2 v	3 v	4 v	5 v	6 v	7 v	8 v	8.5 v	9 v	9.5 v	10 v	10.5 v	11 v	Final spg	Final v

Energising checks, load and discharge test carried out to BS6290

Remarks:

Witnessed	Engineer (HCP)	Contractor	Date	Sheet 1 of 1
Print name and sign				

SAMPLE

8.14

Plant item: Cables and terminations	Completed	
Identification/route:	Incomplete	
Contractor:	Pc address – file	
Manufacturer:		
Cable type:		

No	Activity	Witnessed		
		Engineer (HCP)	Contractor	Date
1	Carry out general inspection of cable route.			
2	Check cable ends are correctly identified for each cable and phase(s) end.			
3	Check cable trench is of correct depth, with correct depth of refill sand, cable spacing, tiles and marker tape.			
4	Check arrangement of cables on trays is at correct level, spacing and tidy arrangement.			
5	Check that single core cables in trefoil or flat pattern are correctly secured to tray with straps/cleats/binders of correct material and spacing.			
6	Check duct entries into buildings are secured against moisture penetration, fire hazard or vermin entry.			
7	Check lug is correct size for cable end and termination stud in schedule.			
8	Check cable gland is correct size and type for duty required in schedule.			
9	Check cable boxes/cable ends are prepared for termination to cable manufacturer's recommendations.			
10	HTM 2021: HV Safety Code Rules apply: a. HV d.c. test on each phase group for 15 mins .....kV d.c. b. buried cable: oversheath test for one min .....kV d.c. c. cable IR values between phases and phase to armour to be recorded before and after (a) and (b) HV tests.			

Phase I.R. leakage ma.	R – Y	Y – B	B – R
Phase I.R. leakage ma.	R – arm.	Y – arm.	B – arm.
Oversheath	Armour – earth		I.R.

Witnessed	Engineer (HCP)	Contractor	Date	Sheet 1 of 1
Print name and sign				

8.15

Plant item: CT polarity test (flick test)		Completed	
Identification/location:		Incomplete	
Contractor:		Pc address – file	
Manufacturer:			
Serial Nos/types:			

No	Activity	Witnessed		Date
		Engineer (HCP)	Contractor	
	Polarity and continuity tests For each CT: connect meter (Avo or d.c. voltmeter) across the S1 and S2 terminals; positive to S1 and negative to S2. Apply a low voltage battery supply across the CT. P1/P2 primary input supply: connect negative of battery to P2 side and the positive of battery to P1 side. "Make-break" battery positive/P2 connection. The meter pointer will deflect, +ve/-ve. Correct CT termination/orientation and polarity: +ve deflection on +/P2-make -ve deflection on +/P2-break *Record test results below:*			

Serial nos	Ferrule nos Primary	Ferrule nos Secondary
Polarity correct		
Polarity correct		
Polarity correct		
Polarity correct		
Polarity correct		
Polarity correct		
Polarity correct		
Polarity correct		
Polarity correct		
Polarity correct		

Indicate number of remarks sheets attached

Witnessed	Engineer (HCP)	Contractor	Date	
Print name and sign				Sheet 1 of 1

8.16

Plant item: CT magnetisation characteristics						Completed						
Identification/location:						Incomplete						
Contractor:						Pc address – file						
Manufacturer:												
Activity												
Function, ratio and location	Phase and wire nos	CT terminal nos	Serial nos	CT res (ohm)	Insul res M-ohm	Secondary magnetisation. Curve-Plot: mA against volts						
	– R Y B	–	–	–		V	V	V	V	V	V	V
	– R Y B	–	–	–		V	V	V	V	V	V	V
	– R Y B	–	–	–		V	V	V	V	V	V	V
	– R Y B	–	–	–		V	V	V	V	V	V	V
	– R Y B	–	–	–		V	V	V	V	V	V	V
	– R Y B	–	–	–		V	V	V	V	V	V	V
Remarks:												
Witnessed	Engineer (HCP)	Contractor	Date	Sheet 1 of 1								
Print name and sign												

SAMPLE

Page item: Secondary injection test (SIMT ready)	Company		
Identification of equipment	Equipment		
Contractor	For reference only		
Manufacturer			
Serial No.			
Manufacturer's operations	Setting for tests		
Test	P	F or M	B
General inspection Check connections close at zero for time and follows through Check flag operation Measure time to reset from operation current at 1.01In Check relay operation current Set at 100% Ion, check relay closes at 1.0 Ion and opens commences at 95% before 1.0 Ion current values Check relay bridge continuity near Ion setting and with relay out Check relay CT circuit removed	Ion		

CT ratio / Type	Relay contacts				Relay operating times		
Test equipment recommended at 100% Ion and at applied setting	Ion	Ion 1.0 0.9 1	Pick 1.3 2 2 4	errors	P	F or M	B
Applied setting			2				
Flag reset	Fixed setting applied						
Remarks							

Witnessed	Engineer (HCP)	Contractor	Date	
Print name and sign				Sheet 1 of 1

8.18

Plant item: Secondary injection test (instantaneous relay)	Completed	
Identification/location:	Incomplete	
Contractor: Manufacturer: Serial No:	Pc address – file	

Manufacturer's description	Setting		
Test	R	*Y or N	B
General inspection Check trip isolation contacts Check flag operation Check CT's shorts Plug bridge continuity (Inst o/c relays)			

R		*Y or N		B	
Plug setting	Op amps	Plug setting	Op amps	Plug setting	Op amps
Plug out		Plug out		Plug out	

		R	*Y or N	B
*With stabilising resistor in series and CTs in shunt.	Stab. resistor value			
	Applied setting			
	Operating volts			
	Operating current			

Flag reset	Final setting applied

Remarks:

Witnessed	Engineer (HCP)	Contractor	Date	
Print name and sign				Sheet 1 of 1

Plant item: Secondary injection test – instantaneous relay (voltage operated)	Completed	
Identification/location:	Incomplete	
Contractor:	Pc address – file	
Manufacturer:		
Type: Serial No:		

Manufacturer's description	Setting range				Setting	
Test	R	Y	B			REF
General inspection Check trip isolation contacts Check flag operation Check CT shorts						

Voltage setting	R		Y		B			Voltage setting	REF	
	v	a	v	a	v	a			v	a
Setting ( )								Setting ( )		

At setting with CTs in shunt: setting resistors (ohms) and metrosils in circuit volts ..... amps	At setting with CTs in shunt and setting resistor (ohms) and metrosils in circuit volts ..... amps .....

Flag reset	Final settings applied

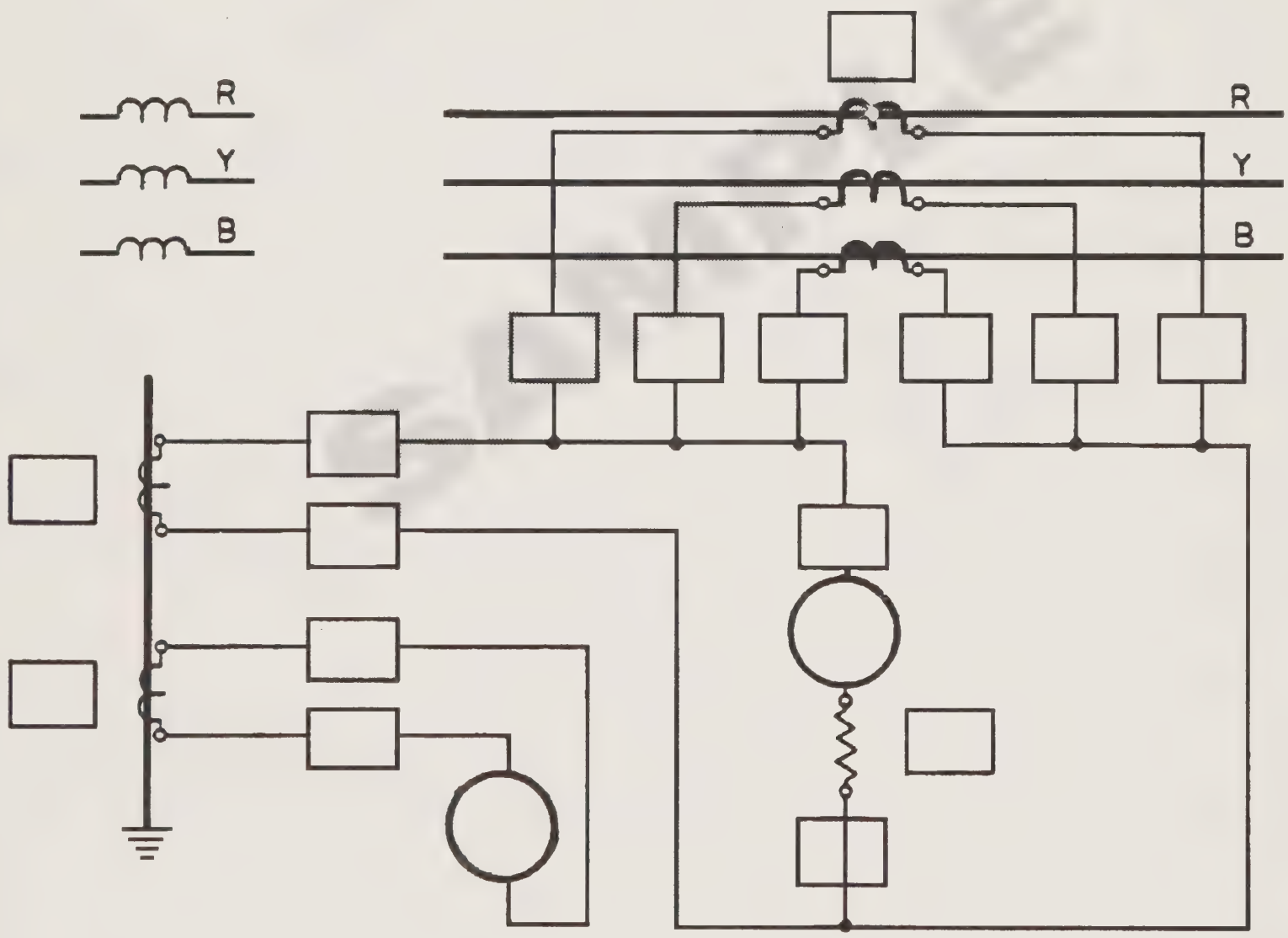
Remarks:

Witnessed	Engineer (HCP)	Contractor	Date	Sheet 1 of 1
Print name and sign				

SAMPLE

Plant item: Restricted and standby earth fault relays (ref & set) Wiring and circuit resistance diagrams	Completed	
Identification/location:	Incomplete	
Contractor: Manufacturer: Cct. diagram. No:	Pc address – file	

No	Activity
	(a) The diagram is to be completed showing the points of injection and measurement. (b) Complete the measurement of the lead resistances, stabilising resistance and the CT resistance and enter the results in the appropriate boxes of the diagram on sheet.



Remarks:

Witnessed	Engineer (HCP)	Contractor	Date	
Print name and sign				Sheet 1 of 1

Plant item: Current transformer – primary injection test	
Identification _____	
Location _____	Manufacturer _____
Contractor _____	Serial No _____

Caution: When conducting these tests, care must be taken not to exceed any limitations, eg current or voltage magnitude and duration ratings, of any associated protection or other apparatus which remains connected during the tests, or of those parts which form the injected current path.

CT duty ratio and injection point	Phases injected	Primary current (amps)	Details of measurements and phases measured	Witnessed		Date
				HCP	Contr.	

Type of instrument: ammeter, voltmeter, etc	Instrument duty	Serial no	Scale range	Current volts, watts/ vars injected	Power factor	Instrument transformer ratio	Instrument reading	How operated (inst. trans., transducer, etc)	Complete / Incomplete
									Pc address file

8.22

Plant item: Electrode – soil resistivity		Completed	
Identification/location:		Incomplete	
Contractor:		Pc address – file	
Manufacturer:			
Serial No:			

No	Activity	Witnessed		
		Engineer (HCP)	Contractor	Date
1	Select from the site map a grid area where earth electrode bank may be installed.			
2	Record area on site area plan.			
3	Set in-line, test spikes as stated in earth tester instrument operating instructions for a single electrode.			
4	Record earth tester displayed resistance (Rm) reading in ohms.			

Rod/group	Resistance (Rm)	Resistivity (P)

5 Convert resistance to resistivity (P) in ohm-metres:

P = 2naRm ohm-metre
=

where a = distance between test spikes (metres)
Rm = displayed/calc. resistance (ohms)
Ref BS7430:1991

Witnessed	Engineer (HCP)	Contractor	Date	
Print name and sign				Sheet 1 of 1

SAMPLE

Plant item: Main/lightning earth electode resistance		Completed	
Identification/location:		Incomplete	
Contractor:		Pc address – file	
Manufacturer:			
Serial No:			

No	Activity	Witnessed		
		Engineer (HCP)	Contractor	Date
1	Check terminal connections of earth electrodes are located below ground level, enclosed in concrete boxes and identified by the approved nomenclature.			
2	Check omissions, approved terminations and cleanliness of finish of all main earth connecting conductors.			
3	Check all main earth bar terminations are singly connected.			
4	Earth electrode: dia , length , no			
5	Set out, in-line: test spike A at 25 m radius and test spike B at 50 m radius to main earth electrodes and connect a 250 vac earth tester, or			
6	connect 250 vac power source and multi-ammeter between earth electrode and test spike B with a 10 kohm per volt voltmeter between earth electrode and test spike A.			
7	Record earth test resistance or calc.			

Electrode	volts	amps	res. ohms
Full group			
Half group 1			
Half group 2			

Note: adjust radius of test spike A for steady resistance.

8	Repeat (5) or (6) with main electrode group split into half groups.		
9	Remake connections and:		
10	Check all bolted terminal connections are weatherproof.		

Witnessed	Engineer (HCP)	Contractor	Date	Sheet 1 of 1
Print name and sign				

Other publications in this series

(Given below are details of all Health Technical Memoranda available from HMSO. HTMs marked (*) are currently being revised, those marked (†) are out of print. Some HTMs in preparation at the time of publication of this HTM are also listed.)

1 Anti-static precautions: rubber, plastics and fabrics*†
2 Anti-static precautions: flooring in anaesthetising areas (and data processing rooms)*, 1977.
3 –
4 –
5 Steam boiler plant instrumentation†
6 Protection of condensate systems: filming amines†
8 –
9 –
10 Sterilizers*†
2011 Emergency electrical services, 1993.
12 –
13 –
2014 Abatement of electrical interference, 1993.
15 Patient/nurse call systems†
16 –
17 Health building engineering installations: commissioning and associated activities, 1978.
18 Facsimile telegraphy: possible applications in DGHs†
19 Facsimile telegraphy: the transmission of pathology reports within a hospital – a case study†
2020 Electrical safety code for low voltage systems, 1993.
2021 Electrical safety code for high voltage systems, 1993.
22 Piped medical gases, medical compressed air and medical vacuum installations*†
22 Supp. Permit to work system: for piped medical gases etc†
23 Access and accommodation for engineering services†
24 –
25 –
26 Commissioning of oil, gas and dual fired boilers: with notes on design, operation and maintenance†
27 Cold water supply storage and mains distribution* [Revised version will deal with water storage and distribution], 1978.
28 to 39 –
2040 The control of legionellae in healthcare premises – a code of practice, 1993.
41 to 53 –

Component Data Base (HTMs 54 to 70)

54.1 User manual, 1993.
55 Windows, 1989.
56 Partitions, 1989.
57 Internal glazing, 1989.
58 Internal doorsets, 1989.
59 Ironmongery, 1989.
60 Ceilings, 1989.
61 Flooring, 1989.
62 Demountable storage systems, 1989.
63 Fitted storage systems, 1989.
64 Sanitary assemblies, 1989.
65 Signs†
66 Cubicle curtain track, 1989.
67 Laboratory fitting-out system, 1993.
68 Ducts and panel assemblies, 1993.
69 Protection, 1993.
70 Fixings, 1993.
71 to 80 –

Firecode

81 Firecode: fire precautions in new hospitals, 1987.
81 Supp 1, 1993.
82 Firecode: alarm and detection systems, 1989.
83 Fire safety in health care premises: general fire precautions*†
85 [Revision to Home Office draft guidance in preparation]
86 Firecode: assessing fire risks in existing hospital wards, 1987.
87 Firecode: textiles and furniture, 1993.
88 Fire safety in health care premises: guide to fire precautions in NHS housing in the community for mentally handicapped/ill people, 1986.

New HTMs in preparation

Lifts

Combined heat and power

Telecommunications (telephone exchanges)

Washers for sterile production

Ventilation in healthcare premises

Risk management and quality assurance

Health Technical Memoranda published by HMSO can be purchased from HMSO Bookshops in London (post orders to PO Box 276, SW8 5DT), Edinburgh, Belfast, Manchester, Birmingham and Bristol or through good booksellers. HMSO provide a copy service for publications which are out of print; and a standing order service.

Enquiries about Health Technical Memoranda (but not orders) should be addressed to: NHS Estates, Department of Health, Publications and Marketing Unit, 1 Trevelyan Square, Boar Lane, Leeds LS1 6AE.

About NHS Estates

NHS Estates is an Executive Agency of the Department of Health and is involved with all aspects of health estate management, development and maintenance. The Agency has a dynamic fund of knowledge which it has acquired during 30 years of working in the field. Using this knowledge NHS Estates has developed products which are unique in range and depth. These are described below.

NHS Estates also makes its experience available to the field through its consultancy services.

Enquiries should be addressed to: NHS Estates, Department of Health, 1 Trevelyan Square, Boar Lane, Leeds LS1 6AE. Telephone: 0532 547000.

Some other NHS Estates products

Activity DataBase – a computerised system for defining the activities which have to be accommodated in spaces within health buildings. *NHS Estates*

Design Guides – complementary to Health Building Notes, Design Guides provide advice for planners and designers about subjects not appropriate to the Health Building Notes series. *HMSO*

Estatecode – user manual for managing a health estate. Includes a recommended methodology for property appraisal and provides a basis for integration of the estate into corporate business planning. *HMSO*

Capricode – a framework for the efficient management of capital projects from inception to completion. *HMSO*

Concode – outlines proven methods of selecting contracts and commissioning consultants. Both parts reflect official policy on contract procedures. *HMSO*

Works Information Management System – a computerised information system for estate management tasks, enabling tangible assets to be put into the context of servicing requirements. *NHS Estates*

Option Appraisal Guide – advice during the early stages of evaluating a proposed capital building scheme. Supplementary guidance to Capricode. *HMSO*

Health Building Notes – advice for project teams procuring new buildings and adapting or extending existing buildings. *HMSO*

Health Facilities Notes – debate current and topical issues of concern across all areas of healthcare provision. *HMSO*

Health Guidance Notes – an occasional series of publications which respond to changes in Department of Health policy or reflect changing NHS operational management. Each deals with a specific topic and is complementary to a related Health Technical Memorandum. *HMSO*

Encode – shows how to plan and implement a policy of energy efficiency in a building. *HMSO*

Firecode – for policy, technical guidance and specialist aspects of fire precautions. *HMSO*

Nucleus – standardised briefing and planning system combining appropriate standards of clinical care and service with maximum economy in capital and running costs. *NHS Estates*

Concise – software support for managing the capital programme. Compatible with Capricode. *NHS Estates*

Items noted "HMSO" can be purchased from HMSO Bookshops in London (post orders to PO Box 276, SW8 5DT), Edinburgh, Belfast, Manchester, Birmingham and Bristol or through good booksellers. Details of their standing order service are given at the front of this publication.

Enquiries about NHS Estates products should be addressed to: NHS Estates, Marketing and Publications Unit, Department of Health, 1 Trevelyan Square, Boar Lane, Leeds LS1 6AE.

NHS Estates consultancy service

Designed to meet a range of needs from advice on the oversight of estates management functions to a much fuller collaboration for particularly innovative or exemplary projects.

Enquiries should be addressed to: NHS Estates Consultancy Service (address as above).

Printed in the United Kingdom for HMSO.
Dd 297575 C15 11/93 17647

Department of Health

Scottish Office

Welsh Office

Department of Health
and Social Services
Northern Ireland

Health Technical Memorandum 2007 supersedes HTM 7 of the same title published in 1977. It focuses on the legal and mandatory requirements, design applications, maintenance, and operation of electrical services supply and distribution in all types of healthcare and personal social services premises.

It is published as four separate volumes, each addressing a specialist discipline.

This volume – 'Validation and verification' – details the requirements for ensuring that manufactured equipment is formally tested and certified as to contract, and manufactured to the highest level of quality assurance. The importance of commissioning is emphasised and the order of tests on site is listed. Routine testing, which is a subset of these commissioning tests, is also reviewed.

HMSO

HMSO publications are available from:

HMSO Publications Centre
(Mail, fax and telephone orders only)
PO Box 276, London, SW8 5DT
Telephone orders 071-873 9090
General enquiries 071-873 0011
(queuing system in operation for both numbers)
Fax orders 071-873 8200

HMSO Bookshops
49 High Holborn, London, WC1V 6HB
(counter service only)
071-873 0011 Fax 071-873 8200
258 Broad Street, Birmingham, B1 2HE
021-643 3740 Fax 021-643 6510
33 Wine Street, Bristol, BS1 2BQ
0272 264306 Fax 0272 294515
9-21 Princess Street, Manchester, M60 8AS
061-834 7201 Fax 061-833 0634
16 Arthur Street, Belfast, BT1 4GD
0232 238451 Fax 0232 235401
71 Lothian Road, Edinburgh, EH3 9AZ
031-228 4181 Fax 031-229 2734

HMSO's Accredited Agents
(see Yellow Pages)

and through good booksellers

HMSO C

ISBN 0-11-321686-6

9 780113 216864

Health Technical Memorandum 2007

Electrical services: supply and distribution

Validation and verification

NHS Estates

HMSO